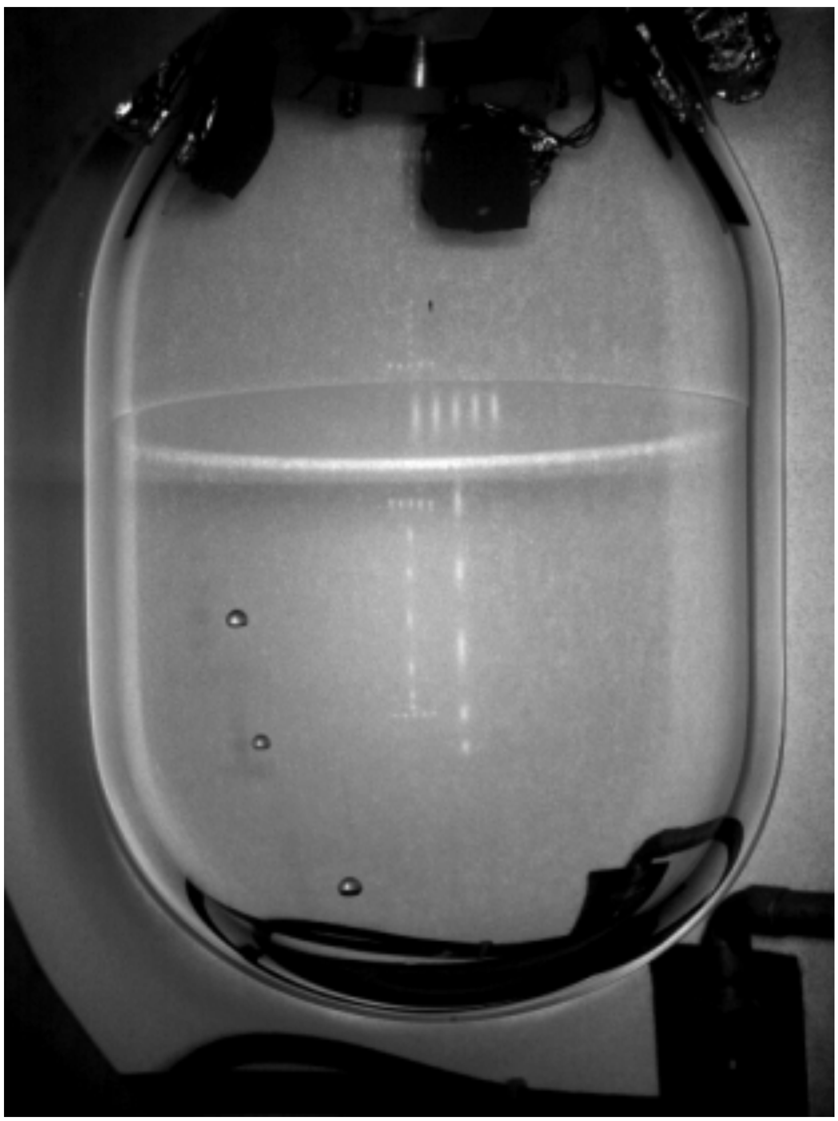
Accord Among

COUPP, SNOLAB, and Fermilab

To Operate the COUPP 2 Liter Bubble Chamber at SNOLAB

June 16 2010



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Introduction

The Memorandum of Understanding between Fermilab and SNOLAB expresses the intention to promote cooperation by undertaking joint collaboration for research and development in areas of mutual interest. This Accord is such a collaboration. It covers the installation, commissioning, and operations of the COUPP 2 liter bubble chamber in a deep underground location at SNOLAB.

The accord is intended to provide a work allocation for SNOLAB, Fermilab, and the participating institutions. It reflects an arrangement that currently is satisfactory to the parties; however, it is recognized and anticipated that changing circumstances of the evolving research program will necessitate revisions. The parties agree to negotiate amendments to this memorandum that will reflect such required adjustments.

COUPP Personnel and Institutions

Spokesperson: Juan Collar

Institutions:
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Overview

The COUPP 2-liter bubble chamber is an upgrade of the original 1-liter COUPP bubble chamber which was designed and constructed at the University of Chicago in 2004 and was in operation in the MINOS near detector hall at Fermilab from 2005 through 2008. The early work with the 1-liter chamber demonstrated the technical feasibility of a large, clean, continuously stable bubble chamber as a dark matter detector and the exceptional $\sim 10^{10}$ rejection of gamma and beta recoil backgrounds, and produced new limits[1] on spin-dependent WIMP-nucleus interactions.

While notably successful in gamma and beta recoil discrimination, the maximum size of a dark matter bubble chamber was technically limited by the rate of bubble nucleation on the vessel walls, and the physics reach of the bubble chamber technique has been limited by background events due to alpha decays of unstable nuclei within the bubble chamber fluid. The COUPP 2–liter bubble chamber upgrade was initiated with three specific goals:

1) *Test the use of a synthetic silica inner vessel* to eliminate bubble nucleation on the vessel walls. The working theory was that this class of events was due to alpha particle emissions from the vessel walls arising from the intrinsic Uranium and Thorium contamination of natural quartz.
2) *Demonstrate Improved fluid handling* procedures to minimize the injection of radon into the vessel during filling.

1 *"Spin Dependent WIMP Limits from A Bubble Chamber"* Science 319:933-936,2008

3) *Evaluate the acoustic alpha recoil discrimination* reported[2] by the PICASSO collaboration.

The COUPP 2-liter bubble chamber was installed in the MINOS near detector hall at Fermilab in August 2009 and ran through December 2009. It was successful in each of its stated goals. The synthetic silica vessel reduced the wall nucleation rate to a level sufficiently low for the largest chambers currently under consideration. By better choices of plumbing materials, the intrinsic alpha emitter contamination of the bubble chamber fluid was reduced to ~1 event/kg/day. Most important, the test resulted in a spectacular confirmation[3] of acoustic alpha discrimination, and in new world best limits for spin-dependent WIMP interactions[4].

Because the capabilities of the COUPP-2 liter bubble chamber were limited by the cosmic ray backgrounds at the 300-foot depth of the Fermilab MINOS site, the experiment will be moved from Fermilab to SNOLAB where it will operate at a depth of 6800 feet. The goals of this deep site run are[5]:-

1) Conduct a run with the world's best physics reach for spin-dependent WIMP-nucleus scattering and a reach in the spin-independent mode that is among the world's best.
2) Measure the level of acoustic alpha rejection at the 10,000/1 level
3) Establish all the elements needed to operate COUPP bubble chambers at SNOLAB. This will smooth the process of bringing future chambers deep underground (e.g. the upcoming 60kg device).

Intellectual Property

The parties agree that they each have a royalty-free license to use intellectual property described in the Accord provided by the other parties only for the experiment described in the Accord.

Resource Requirements

Exclusive of its shielding, the COUPP 2-liter bubble chamber experiment is a very small and easily portable device consisting of the bubble chamber itself, a small hydraulic controls unit, a small laboratory NESLAB heater/chiller unit, and a single data acquisition relay rack. The combined weight of all the elements (again

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[2] Aubinet al., arXiv:0807.1536

[3] "*COUPP progress report: results from the 4kg test chamber*" C. Eric Dahl (Univ. of Chicago), Ninth UCLA Symposium on Sources and Detection of Dark Matter and Dark Energy in the Universe, Feb 24-25, 2010.

[4] *"New Dark Matter Limits from COUPP,"* Jeter Hall, Fermilab Joint Experimental Theoretical Seminar, March 19, 2010.

[5] *"COUPP Deep Underground Deployment Plan"* available from http://coupp-docdb.fnal.gov/cgi-bin/ShowDocument?docid=51

exclusive of the veto/shielding) is less than 2000 lb and could be delivered in a single truckload. The COUPP 2-liter bubble chamber is illustrated in **Figure 1**.

At the 6800-foot depth of the SNOLAB site, the experiment will not require active cosmic ray muon tagging. To shield the experiment against neutrons originating from the radioactivity of the surrounding rocks, the experiment will be surrounded by a thickness of 20 inches (50 cm) of polyethylene/water shielding. An elevation view of the chamber as it will sit in its shielding is provided as **Figure 2**.

The footprint of the experiment is roughly 8' x 12'. This space is sufficient to contain the polyethylene/water shielding, the hydraulic cart, the NESLAB heater/chiller unit, the data acquisition rack, and a chair.

The data acquisition rack requires a single 60 Hz, 110V, 20A circuit. The hydraulic cart is powered from the data acquisition rack. The NESLAB heater/chiller unit requires a separate 60 Hz, 110V, 20A circuit. To power auxiliary equipment used during installation and commissioning (vacuum pump, oil pump) a third separate outlet would be convenient. The hydraulic cart additionally requires a compressed air supply at >50 psig. The operation of the experiment consumes compressed air at a rate of less than 10 SCF per day.

The run plan includes the use of radioactive sources for calibration. The chamber will be equipped with a source tube through which sources can be moved to a fixed position external to the pressure vessel. It is expected that ^{137}Cs sources will be used with strengths ranging from 0.1 μCi to 1 mCi to study electron recoil event rejection and a very weak neutron source (~5 n/s), either AmBe or Californium will be needed to understand the nuclear recoil response. In addition a weak thoron source is being developed for installation at a later date to dope the chamber fluid for alpha discrimination studies. SNOLAB procedures for the handling and transport of radioactive sources and for bringing sources onsite will be followed at all times.

Despite the key role played by the acoustic signature of each bubble in the identification of nuclear recoil events, no special considerations for environmental acoustic noise are anticipated. The acoustic sensors operated successfully in a very noisy environment in the NuMI area at Fermilab. It would however be prudent to avoid the close proximity to any vibrating or noisy equipment.

Resource Requirements Summary:

The resources are needed on surface during initial testing and underground for physics running.

Footprint:	8 x 12 feet ~100 square feet
Electrical:	(3) 60Hz, 110V, 20A circuits
Network:	100Mbps
Compressed Air:	>50 psig, <10 SCF/day

Radioactive Sources (only needed underground):

Encapsulated neutron source ~5 n/s, either AmBe or ^{252}Cf
Encapsulated ^{137}Cs gamma sources., 0.1 μCi to 1 mCi
Weak thoron source

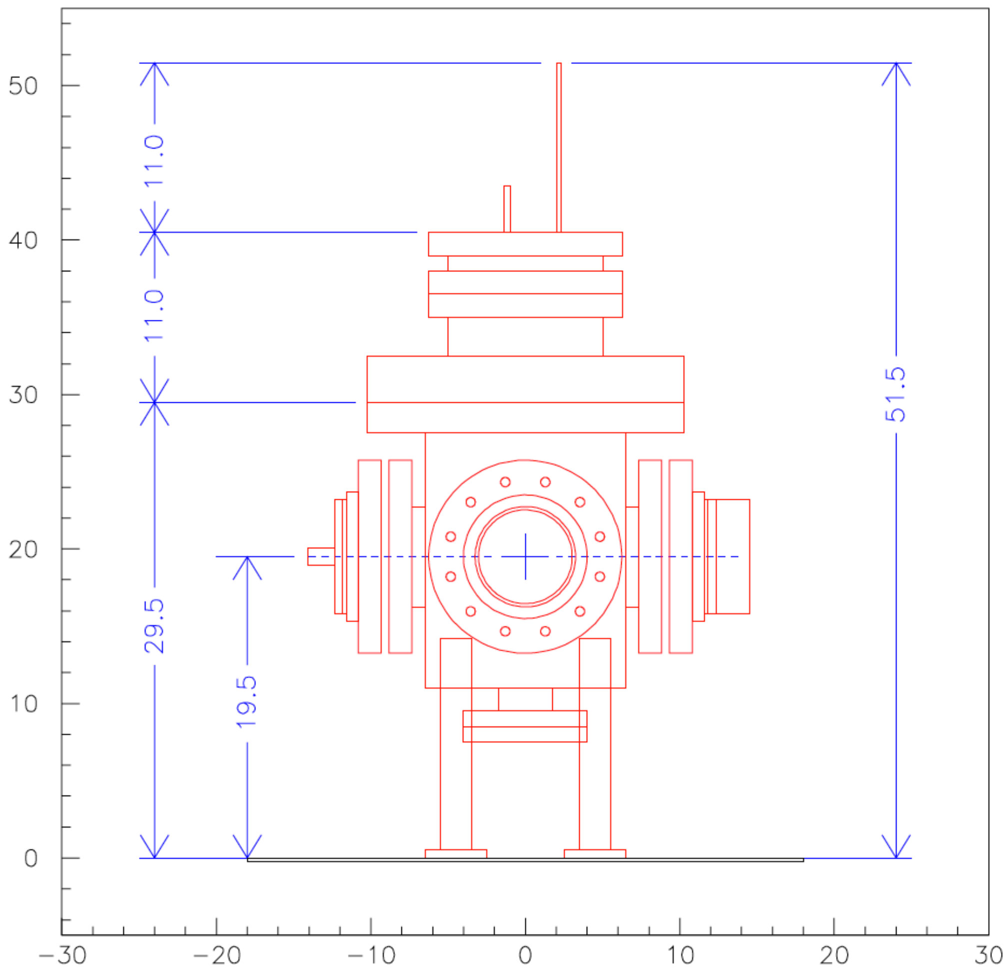

Figure 1: An Elevation View Cartoon of the COUPP 2 Liter Bubble Chamber. Dimensions are in inches.

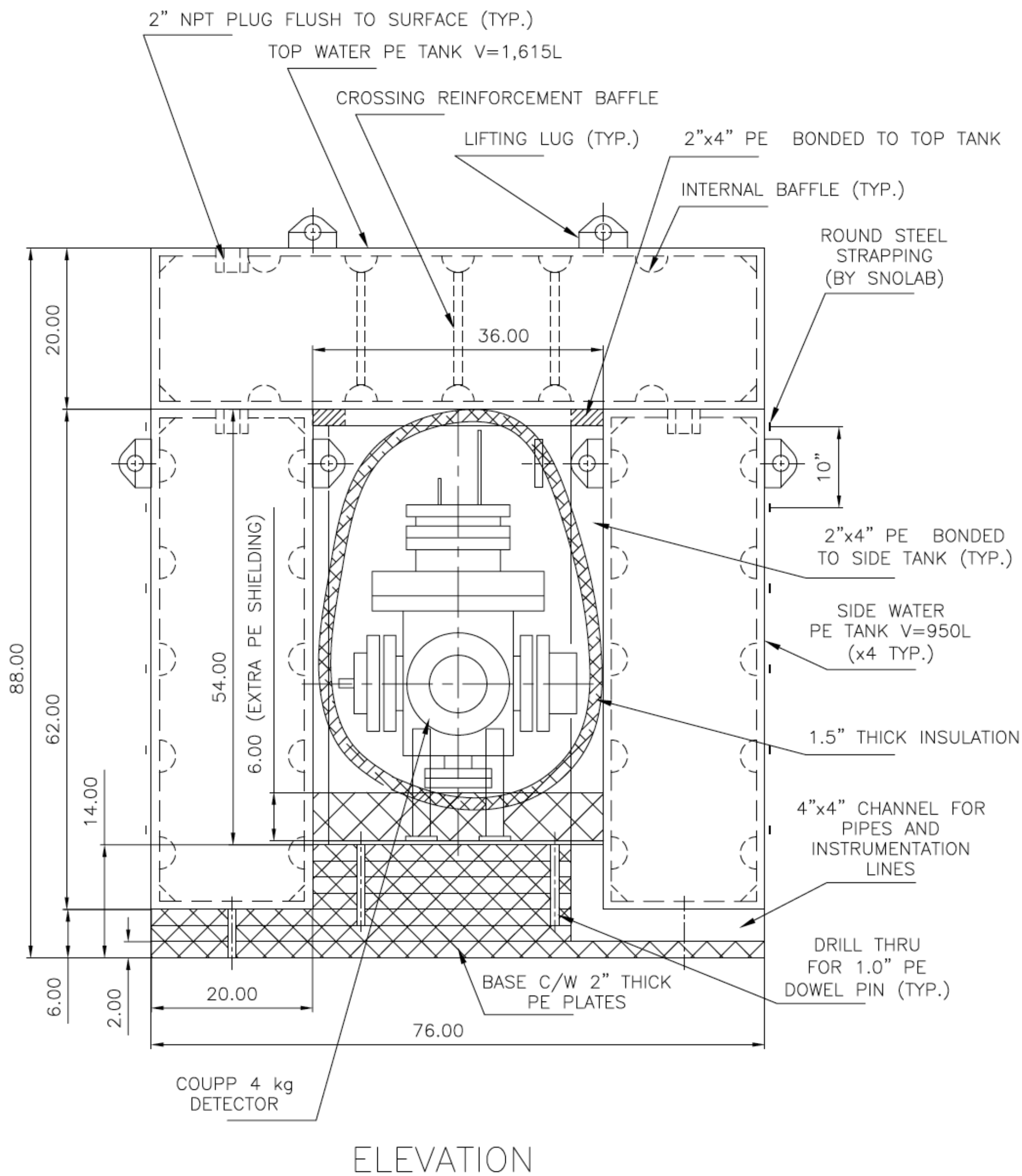

Figure 2: An Elevation Drawing showing the COUPP 2 liter bubble chamber within its polyethylene/water shielding.

Figure 3: This photograph shows the COUPP 2-liter bubble chamber as it appeared in the Fermilab MINOS area installation. The Hydraulic Controls Cart is visible to the left and the NESLAB RTE-740 heater/chiller unit can be seen behind the chamber.

The Experimental Apparatus:

The elements of the COUPP 2-liter Bubble Chamber Experiment are listed below:

1) The Shielding consists of
    a. Base Slab of polyethylene 76” square, 6” high with additional raised polyethylene pedestal base 36” square, 8”high.
    b. Four Polyethylene/water side shield tanks 20”x56”x62” high.
    c. One Polyethylene/water top shield tank 76”x76”x20”high.

2) The Bubble Chamber
    a. One stainless steel pressure vessel, including
        i. Pressure Vessel Body
        ii. Pressure Vessel load distributing base plate
        iii. Top and bottom flanges
        iv. Top Flange Spacer
        v. Internal Heater/chiller coils
        vi. Four pressure rated 6” diameter viewports
        vii. Retro-reflective backdrop for photography
        viii. Two FireWire video cameras
        ix. LED array for photography illumination

    b. Inner vessel Assembly, including
        i. Quartz inner vessel
        ii. Pressure balancing bellows
        iii. Top flange assembly, plumbing and valves
        iv. Instrumentation (temperature and pressure transducers)
        v. Instrumentation (acoustic transducers)
        vi. Instrumentation wiring, feed-through, and breakout box.

3) The Data Acquisition and Controls Rack, including
    a. One National Instruments PXI Chassis with instrumentation modules
    b. One 1U rack-mount National Instruments SC-2345 Instrumentation Wiring Chassis.
    c. Two LINUX computers (one for data management and communications, one hot spare.)
    d. Auxiliary electronics modules
        i. 1U rack-mount Acoustic Transducer Bias Supply
        ii. 1U rack-mount LED driver module
        iii. A small commercial bias supply for a fast pressure transducer.

4) The Hydraulic Cart which includes
    a. Compressed air system

  b. Fast solenoid actuated pneumatic/hydraulic cylinder for fast compression
  c. Stepping motor driver slow hydraulic cylinder for pressure control
  d. Pressure and temperature instrumentation
  e. Commercial controls processor
  f. Hydraulic plumbing connection to the bubble chamber pressure vessel.

5) The NESLAB heater/chiller unit
  a. A commercial NESLAB RTE-740 laboratory circulating heater/chiller
  b. Insulated circulation lines connecting the NESLAB bath to the heater/chiller coils in the bubble chamber pressure vessel

6) Cable Plant
  a. Roughly one dozen instrumentation, control, and network cables are required for the experiment

7) Auxiliary Equipment
  a. Vacuum Pump used in fluid handling and setup operations.
  b. Propylene glycol is (2) five-gallon plastic containers.
  c. Glycol handling hose and valve.
  d. CF_3I transport and handling equipment
    i. 4-liter Swagelok sample cylinder used for transport and transfer.
    ii. CF_3I transfer line
    iii. Refrigerant scale used to meter CF_3I transfer.
  e. Dummy hydraulic load for use in commissioning and testing the hydraulic cart with the DAQ.
  f. Dummy thermal bath load for use in commissioning and testing the NESLAB heater/chiller unit with the DAQ.
  g. Radioactive sources for use in chamber calibration and testing
    i. Sealed gamma sources 1-100 μCi
    ii. Sealed neutron sources ~few neutrons per second

The Deployment Plan:

Four Sequences of Events:

The plan for getting the experiment ultimately assembled in the SNOLAB underground facility breaks into 4 threads as outlines below. The goal is to have these threads come together in ~August 2010 with the underground commissioning of the experiment.

1) Underground Site Preparation

a. Agree upon a final location and footprint for the experiment
b. Prepare and approve final drawings for the
    i. The experiment layout
    ii. Shielding elements
    iii. Electrical, compressed air, network, and fire protection distribution

c. Procure shielding elements
    i. Base slab and pedestal, side and top tanks

d. Ship Pressure Vessel and Pressure Vessel Base Plate to SNOLAB
e. Clean and Deliver components to SNOLAB Underground area.
f. Execute the Site Preparation Elements, including
    i. Install electrical, compressed air, fire protection, lighting.
    ii. Install and level shielding base slabs and pedestal
    iii. Install pressure vessel on its base plate on the shielding pedestal.

2) DAQ and instrumentation commissioning:

a. Complete DAQ modifications and testing using the Fermilab DAQ at Lab F.
b. Receive new DAQ elements at the Lab 3 North clean room at Fermilab
c. Perform First Level Commissioning activities, including
    i. Acceptance testing (where appropriate) of components
    ii. Software installation and configuration
    iii. Network interconnectivity tests.
    iv. Full system DAQ software tests

d. Re-package DAQ equipment for shipment to SNOLAB
e. Receive DAQ equipment at SNOLAB, clean and stage in an above ground laboratory space.
f. Complete Level 2 Commissioning activities, including
    i. Populate Relay racks
    ii. Full system DAQ test
    iii. Network connectivity tests to Fermilab
    iv. Exercise of full data path including analysis and archive tools.

g. Disassemble DAQ elements and prepare for and transport to the site of the underground installation.
h. Set up the DAQ and instrumentation elements in final form in the underground site. This includes
    i. Place and set the hydraulic cart (it has screw jack leveling feet)

   ii. Complete the plumbing connection of the hydraulic cart to the pressure vessel
   iii. Setup the NESLAB unit and complete its insulated plumbing connections to the pressure vessel
   iv. Place the relay racks
   v. Cable the experiment, including
      1. Instrumentation cabling
      2. Control cabling
      3. Network cabling.

   vi. Fill the Pressure Vessel and hydraulic cart with propylene glycol and de-gas.

i. Insulate the pressure vessel
j. Complete Level 3 Commissioning Activities, including:
   i. Exercise the full DAQ and Controls system
   ii. Test Hydraulic Cart function
      1. Expansion/compression
      2. Pressure control
      3. Alarms and Limits

   iii. Test NESLAB temperature Regulation
   iv. Test Auto-Run DAQ capabilities
   v. Test remote operations functionality,
   vi. Test data path connectivity through to analysis and archiving at Fermilab

3) Inner Vessel Assembly

a. Disassemble the original inner vessel assembly
b. Bag and tag parts for transport to AD A0 cleaning facility
c. Complete the cleaning and parts prep. This includes
   i. Inner vessel components (vessel, bellows, flanges, seals, etc…)
   ii. Water distillation components (still, lines)

d. Assemble the inner vessel (vessel, bellows, and flanges, seals)
e. Final rinse at A0
f. Vacuum leak check.
g. Package and transport to Lab 3 COUPP clean room.
h. Set up and execute water distillation.
i. Setup in the Lab 3 North clean room.
j. Perform sensor installation and wiring, including
   i. Temperature transducers
   ii. Pressure transducers
   iii. Acoustic transducers.

k. Test and calibrate where appropriate transducers.
l. Package the inner vessel assembly for transport
m. Transport the inner vessel assembly and CF3I handling equipment to SNOLAB.
n. Receive, clean, and move underground.
o. At this point, the inner vessel assembly is ready to mate with the already tested pressure vessel, hydraulic cart, NESLAB, and DAQ in the underground site.
p. Install the inner vessel
q. Evacuate and backfill the pressure vessel with glycol
r. Cool the vessel and perform the CF_3I distillation/fill.
s. Warm the chamber to its operating point and execute final commissioning tests, including
    i. Expansion, testing for stability, radon etc.
    ii. Use neutron source to confirm operations.

4) Shielding Tanks

a. Agree upon Final Conceptual Design
b. Obtain quotations based on the preliminary drawings.
c. Finalize the design drawings
d. Procure the Tanks (Are the base slab elements available at an earlier time? The base is needed early. The tank installation is the last installation step.)
e. Receive the tanks, clean transport underground.
f. Test?
g. Install the shielding tanks, fill.

The Run Plan:

It is intended to have all the components of the experiment assembled underground in August 2010. After a period of commissioning that should last about 2 weeks, the experiment will run for several months with the aim of setting world beating dark matter limits and improving the knowledge of acoustic alpha discrimination by an order of magnitude over what was done in the NuMI site at Fermilab. The details of this running are yet to be finalized. Decisions as to how much calibration data to take, whether and how to scan the vessel pressure, and what operating temperature to use need only be decided at the start of the run and after more experience is gained in underground operations. It is certainly the case that neutron and, probably, gamma sources will be needed at various times for chamber calibration.

It is anticipated that after several months of operation the 2 liter device discussed in this document will be joined underground at SNOLAB by the COUPP 30 liter device (the 30 liter device will be the subject of a future accord between COUPP, SNOLAB, and Fermilab). Once the COUPP 30 liter chamber is running it will quickly make the 2 liter obsolete as a dark mater search device. At that point the 2 liter will become the chamber used for precision studies of alpha discrimination using an alpha source[6]. In this mode it can be expected to run for at least another year.

Resources and Responsibilities:

The resources for the experiment will be provided as follows:

Equipment

1) SNOLAB will provide
    a. Site preparation, including
        i. Electrical distribution
        ii. Compressed air
        iii. Fire protection
        iv. Lighting
    b. Shielding, including
        i. Shielding base slab and pedestal
        ii. Shielding tanks, side and top.
    c. Weak neutron sources
    d. Gamma sources

2) University of Chicago Will Provide
    a. The Bubble Chamber Pressure Vessel
    b. The Data Acquisition System
        i. National Instruments PXI Chassis w/ embedded processor
        ii. Data Acquisition Modules
        iii. Software Licenses LabVIEW, LabVIEW VISION
        iv. Instrumentation Cabling
    c. Linux data handling computers (2)
    d. 19" Racks (2) with rack mounted monitors and keyboards
    e. The heater/chiller

3) Indiana University South Bend Will Provide
    a. Acoustic Transducers

4) Fermilab Will Provide:

[6] *"COUPP Deep Underground Deployment Plan"* available from http://coupp-docdb.fnal.gov/cgi-bin/ShowDocument?docid=51

a. The Hydraulic Controls Cart
b. The Inner Vessel Assembly
c. The Acoustic Transducer Biasing Module
d. The Photography elements, including
    i. FireWire Cameras
    ii. LED array
    iii. CAMERA/LED Interface Module
    iv. Retro-reflective backdrop
e. Readout Components for the Acoustic Transducers, including
    i. Preamplifier boards
    ii. Acoustic transducer bias box

Travel

All travel to SNOLAB for installation and operation of the experiment will be paid for by the University of Chicago NSF S4 grant

Engineering and Technician Support From SNOLAB will include:

1) Engineering and Design Support for Site Preparation
    a. Appropriate drawings and specifications for
        i. Lighting and Electrical distribution
        ii. Compressed air Distribution
        iii. Fire Protection
        iv. Network Distribution
2) Engineering and Design Support for Shielding
3) Technician and other appropriate labor for
    a. Installation of Site Infrastructure (lights, power, compressed air fire protection, network.)
    b. Installation of Shielding Base and Pedestal
    c. Installation of Shielding tanks
    d. Cleaning and underground transport of the COUPP experimental apparatus

Engineering and Technician Support From Fermilab:

PPD Mechanical Department Support

e. Process Flow Diagram
    i. Drafting for the Diagram
    ii. Mechanical Tech for component checking and tagging
    iii. Engineering Support for review and approval

f. The Hydraulic Cart

i. Mechanical Tech Support for revising the cart plumbing. This includes specification, procurement, and installation of new plumbing components.
ii. Mechanical Tech Support for specifying and procuring plumbing components to connect the hydraulic cart to the experiment pressure vessel.

g. The Inner Vessel Assembly
   i. Mechanical Tech Support for specification and procurement of miscellaneous expendables of the Inner Vessel Assembly. These include:
      1. Filters,
      2. Seals,
      3. Valve kits.

   ii. Mechanical Tech Support for disassembling the inner vessel components and for bagging and tagging them.
   iii. Mechanical Tech Support for overseeing the transport of inner vessel components to the Accelerator Division A0 Cleaning Facility.
   iv. Mechanical Tech Support for Assembly of the inner vessel components. This includes
      1. Assembly and sealing of the top flange, the bellows, and the inner vessel
      2. Final rinse of the inner vessel assembly
      3. Vacuum Leak Checking
      4. Preparation of top flange components
         a. Valves assemblies
         b. Electrical feed-through
         c. Sensor attachment and wiring

   v. Mechanical Tech Support for Water Fill/Distillation
      1. Mobilization of still components
      2. Overseeing the cleaning of still components at A0 (this task is likely integrated with the cleaning of the inner vessel components.)
      3. Assembly and preparation for the water distillation apparatus in the Lab 3 Clean Room.
      4. Execution of the water distillation process

   vi. Preparation of the Inner Vessel Assembly for Transport.
   vii. One week of travel to SNOLAB by a mechanical tech to carry out final installation of inner vessel assembly into pressure vessel.

PPD Technical Centers Department Support

h. Design and Fabrication support for Auxiliary Shielding Pieces surrounding the chamber legs.
i. Installation Support and Maintenance for KEPDirect PLC firmware and communications software.

PPD Electrical Engineering Department Support

j. Engineering Design for Acoustic Transducer preamplifier boards
k. Fabrication and assembly for preamplifier boards
l. Engineering Design Support for Acoustic Transducer Bias Box modifications
m. Engineering Design Support for Camera/LED interface box revisions.
n. Engineering Design Support for Modifications to Hydraulic Cart Interface Box.

Summary of Costs

	Engineer time	Technician Time	M&S	Travel
SNOLAB	---	---	---	
Fermilab-PPD-Mech	4 days	4 weeks		
Fermilab-PPD-Tech	4 days	1 week		
Fermilab-PPD-EE	3 days	1 week		
University of Chicago (Collar Group)			$47k	$30k

Special Considerations

1. To carry out the experiment a number of Environmental, Safety and Health (ES&H) reviews are necessary. The Spokesperson will follow those procedures in a timely manner, as well as any other safety requirements put forth by SNOLAB.

2. All regulations concerning radioactive sources will be followed. No radioactive sources will be carried onto the SNOLAB site or moved without the approval of the SNOLAB radiation safety officer.

3. The experimenters will be responsible for maintaining both the electronics and the computing hardware supplied by them for the experiment

4. Upon completion of the experiment the experimenters agree to remove their experimental equipment as SNOLAB requests them to. They agree to remove it expeditiously and in compliance with all ES&H requirements, including those related to transportation. All the expenses and personnel for the removal will be borne by the experimenters unless removal requires facilities and personnel not able to be supplied by them, such as rigging, crane operation, etc.

Internal Fermilab Signatures:

____ / / 2010
Vicky White, Computing Division

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Michael Lindgren, Particle Physics Division

____ / / 2010
Nancy Grossman, ES&H Section

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Greg Bock, Associate Director, Fermilab

Signatures:

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Juan Collar, COUPP Spokesperson

____ / / 2010
Greg Bock, Associate Director, Fermilab

____ / / 2010
Nigel Smith, Director, SNOLAB

Appendix I: - Hazard Identification Checklist

Cryogenics		**Electrical Equipment**		**Flammable Gases or Liquids**	
	Beam line magnets		Cryo/Electrical devices	Type:	
	Analysis magnets		capacitor banks	Flow rate:	
	Target		high voltage	Capacity:	
	Bubble chamber		exposed equipment over 50 V	**Hazardous/Toxic Materials**	
Pressure Vessels		**Other Gas Emissions**		List hazardous/toxic materials planned for use in an experimental enclosure:	
12inch	inside diameter	Type:			
220 PSI	operating pressure	Flow rate:			
glass	window material	Capacity:			
1 inch	window thickness	**Radioactive Sources**			
Vacuum Vessels			permanent installation		
5.8 inch	inside diameter	**X**	temporary use		
vaccuum	operating pressure	Type:	**Cf neutron**		
quartz	window material	Strength:	**5 n/sec**		
1/8 inch	window thickness	**Hazardous Chemicals**			
Lasers			Cyanide plating materials		
	Permanent installation		Scintillation Oil		
	Temporary installation		PCBs		
	Calibration		Methane	**Mechanical Structures**	
	Alignment		TMAE	**X**	Lifting devices
type:			TEA		Motion controllers
Wattage:			photographic developers		scaffolding/elevated platforms
class:			Other: Activated Water?		Others